STATE OF MICHIGAN

JOHN ENGLER, Governor

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Evaluation of the Risk of Cancer among Fire Fighters

June 1999

On August 5, 1998, Governor John Engler requested that the Michigan Environmental Science Board (MESB) conduct an evaluation of the presumption that there exists a causal relationship between cancer and the fire fighter occupation (Attachment 1). Specifically, the MESB was requested to:

1. Evaluate the available cancer and occupational health scientific evidence regarding the level of risk posed to fire fighters from occupational exposure to toxic and cancer-causing substances; and

2. Provide a determination of the level of cancer risk that can be expected in this occupational group taking into account confounding factors such as smoking, frequency and duration of exposure to hazardous substances, and use and nonuse of hazardous material personal protection equipment.

A Panel, composed of four MESB members and one guest scientist, was convened on October 26, 1998, to address the Governor's request (Attachment 2). Three meetings of the Panel were held. The investigation consisted of the accumulation and evaluation of peer-reviewed and some non peer-reviewed literature and data on the subject. In addition, verbal and written statements from academic experts and industry specialists were considered. The Panel focused its evaluation on two areas: exposure of fire fighters to hazardous and toxic environments and the prevalence of cancer of all types among fire fighters. Presented below are the Panel's findings and conclusions.

Attachment 3 presents an evaluation of fire fighters' exposures. Based on a review of the available data, ample documentation for potential and actual exposure of fire fighters to carcinogenic chemicals exists in the literature. Consequently, it is reasonable to conclude that fire fighters, as a class, suffer greater exposure to toxic and carcinogenic chemicals than the general population, although a quantification of that exposure and the resulting dose on an individual basis is currently not possible. Proper and maximum use of personal protective equipment, while certainly useful to help mitigate most exposures, is not fail-safe against some exposures, given the realities of the fire fighting profession.

Attachment 4 presents an evaluation of 23 epidemiological studies conducted to investigate a possible link between the incidence of cancer and the occupation of fire fighting. This review of available, published information was conducted to determine if a relationship between the occupation and an increased cancer risk could be detected and if so, to quantify it. Quantitative risk assessment seeks to measure the increased risk in a specific population of a specific health outcome, such as cancer or a particular type of cancer, due to a specified exposure. Such measures require data regarding the specific exposure such as the chemicals involved, their dose, duration and constancy. A very rough approximation is sometimes made using years of employment in specific occupations when the exposures are known. In the studies that the Panel reviewed, even when the length of employment as a fire fighter was assessed in relation to cancer risk, there was insufficient information provided or collected on the specific exposures or categories of exposures. Consequently, the Panel was unable to carry out a quantitative risk assessment based of any of the studies reviewed. Despite this, the Panel concludes that the evidence for certain cancer sites is suggestive of an increased risk in fire fighters.

For brain cancer, fire fighters with longer years of exposure appear to have some elevated risk. Similarly, there is some evidence of increased risk of stomach cancer among fire fighters with 30 plus years of exposure. These results must be considered in the context of the small number of cases upon which these observations were made. For lung cancer, skin cancer, and leukemias and lymphomas, the weight of evidence of each of these sites indicates no elevated risk. The few studies that did find excess risk warrant further investigation to attempt to resolve the conflicting evidence.

It is important to recognize that the majority of the evaluated studies found no elevated risk of cancer among fire fighters. In addition, for some cancer sites for which there was suggestion of increased risk, the evidence was often conflicting; e.g., with studies that showed both significantly elevated and significantly decreased risk or studies that showed risk in individuals with less exposure as well as among individuals with more exposure. These apparent conflicts may be due to the low number of cases involved with the studies. Given the limits in study design and exposure measures, additional research will need to focus on the risk of selected cancers, for which limited evidence suggests the possibility of elevated risk, and employ improved measures of exposure.

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Attachment 1. August 5, 1998 Letter from Governor John Engler to the Michigan Environmental Science Board.

STATE OF MICHIGAN
OFFICE OF THE GOVERNOR
LANSING

JOHN ENGLER
GOVERNOR

August 5, 1998

Dr. Lawrence Fischer, Chair
Michigan Environmental Science Board
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Dear Dr. Fischer:

Fire fighters involved in modern building fires may be exposed to a variety of toxic and cancer-causing substances that are produced when chemical components are incinerated. Because of this potential for exposure, it has been suggested that in the absence of confounding factors such as cigarette smoking, sufficient data exist to presume that there exists a causal relationship between respiratory tract, bladder, skin, brain, kidney, blood and lymphatic cancers and the fire fighting occupation. There is a need to research this cancer presumption as it relates to fire fighters.

Given the above, I am requesting that the Michigan Environmental Science Board (Board):

1. Evaluate the available cancer and occupational health scientific evidence regarding the level of risk posed to fire fighters from occupational exposure to toxic and cancer-causing substances, and

2. Provide a determination of the level of cancer risk that can be expected in this occupational group, taking into account confounding factors such as smoking, frequency and duration of exposure to hazardous substances, and use and non-use of hazardous material personal protection equipment.

I am directing the Departments of Community Health and Consumer and Industry Services to fully cooperate with and support the Board's investigation. I would also encourage the Board to seek assistance in this assignment from appropriate federal agencies and its peers in the academic and scientific communities. Please provide me with the results of your evaluation as soon as possible.

Thank you for your continuing service to the citizens of Michigan.

Sincerely,

John Engler
Governor

JE:klk
cc: Mr. Keith G. Harrison, Executive Director, MESB
Ms. Kathleen M. Wilbur, Director, DCIS
Mr. James K. Haveman, Jr., Director, DCH

Attachment 2. Michigan Environmental Science Board Fire Fighter and Cancer Investigation Panel.

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Attachment 3. Fire fighters and cancer risk, summary of exposure studies.

Introduction. In determining the risk from a particular chemical, toxicologists require a measure of the exposure to the chemical or chemicals. For fire fighters, one of the more important routes of exposure is the inhalation route, for which quantification of exposure requires knowledge of the concentration and its duration for each chemical. There may be synergistic or antagonistic effects of simultaneous exposure to multiple chemicals, but analysis of such effects is usually beyond the state of the art at this time. Moreover, any analysis of exposure, and hence any analysis of risk for the fire fighting profession, is rendered nearly impossible by the diversity of combustion situations encountered by each individual. Each fire will have its own blend of combustion products and each fire fighter will have different exposures in each unique fire situation. It is likely that there is no typical exposure that could be related to longevity, frequency of response, geographical practice or other macroscopic variables that could be quantified as a surrogate. Moreover, the materials of construction in buildings have continued to change over the decades of cancer latency usually encountered (Guidotti, 1993).

Review. There have been numerous studies that have attempted to create artificial atmospheres in which laboratory measurements could be made as well as studies in which fire fighters were equipped with portable monitors to document actual exposures. Both are useful for surveying the chemical hazards of the profession. National Institute for Occupational Safety and Health approved personal protective equipment with a required protection factor of 10,000 is in general use and could in theory (Burgess and Crutchfield, 1995a) provide nearly complete inhalation protection, but the practical realities of the profession place weight restrictions on oxygen cylinders that can be carried into the danger zone, and place high priorities on conservation of oxygen for immediate lifesaving situations which compromise the achievement of 100 percent protection. Even in ideal situations of fire access, which allow easy exchange of cylinders, studies have shown that under conditions of high exertion, negative pressure can occur in the self contained breathing apparatus (SCBA) (Burgess and Crutchfield, 1995b) commonly used for personal protection.

In 1972, Ives, Hughes and Taylor, of the National Bureau of Standard's Fire Research and Safety Office, reviewed the available literature to document the "Toxic Atmospheres Associated with Real Fire Situations." The early literature that they reviewed focused on gases which could be readily measured, including CO_2, CO, NH_3, HCN, H_2S, SO_2, HCl, HF, NO_x, Cl_2, $COCl_2$, and general categories of hydrocarbons. The study determined that acute asphyxiants and irritants were produced in large quantities, but did not consider chronic or carcinogenic end points.

Treitman, Burgess and Gold (1980) added the measurement of acrolein and aromatic (benzene) measurements to a chest-mounted air-sampling unit, which was taken by Boston fire fighters into actual fire situations. They documented that over 50 percent of their samples exhibited concentrations of acrolein greater than the American Conference of Governmental Hygienists' Short Term Exposure Limit (STEL), and 10 percent were in excess of the Immediately Dangerous to Life and Health (IDLH) standard. Similar hazards existed for CO, and benzene was detected in almost all samples.

Brown and Birkey (1980) documented the formation of phosgene in the thermal decomposition of polyvinylchloride.

Grand, Haplan and Lee (1981), of the Southwest Research Institute, performed sampling of actual fires in San Antonio residential areas for the Society of the Plastics Industry and the US Fire Administration. They tested for CO, CO_2, HCl, HCN, acetaldehyde, acrolein, and benzene. A value above the IDHC level was found for CO. Benzene was detected in every sample, but in concentrations below the STEL value at that time. Acrolein concentrations exceeded the STEL, but were below the IDLH values. HCN and acetaldehyde were found in concentrations less than the STEL, but were frequently observed.

Lowry *et al.* (1985) monitored actual fires in Dallas and found average concentrations of CO, HCl, HCN, and aldehydes exceeding the STELs.

Atlas *et al.* (1985) used diesel fuel test burns ignited for fire fighter training to obtain emission samples that were subjected to chemical analysis and Ames microbial mutagenesis biological testing. Their ion chromatograms of the particulate phase extract identified pyrenes, napthalenes, anthracenes, and a variety of aliphatic hydrocarbons. Four of the compounds identified were known carcinogens: chrysene, benzo(e)pyrene, benzo(a)pyrene, and benzofluor anthene. These authors concluded that the mutagenic activity was higher in this study than similar results from industrial area air particulates, and appeared to be enhanced over the activity expected from single compounds, suggesting a substantial synergistic effect.

Froines *et al.* (1987) recognized that diesel engine emissions could be present in fire stations due to equipment proximity to living quarters, and therefore conducted in-station sampling in Boston, New York, and Los Angeles, using personal sampling. On a typical day, the authors predict an average particulate exposure of 300 $\mu g/m^3$, compared to a background of 75 $\mu g/m^3$, which seems to be a serious exposure, since most of the excess exposure would be diesel particulate.

Jankovic *et al.* (1991) continued the study of fire fighter exposures, including measurements to evaluate the performance of SCBAs during structural fire fighting. During knockdown they found CO concentrations exceeding 1,500 ppm 10 percent of the time and exceedances of the STEL values for acrolein, formaldehyde, HCl, HCN, and sulfuric acid. Fifty percent of the acrolein samples exceeded the STEL. Concentration levels inside the SCBA mask were well below the STELs, but were measurable (a factor of 3-4 lower) and thought to be associated with usage patterns rather than with leakage. In this study fire fighters were observed to use SCBAs from 20 – 80 percent of the time. Many of the compounds found in knockdown were also detected during overhaul activities, but were low relative to the knockdown values. During knockdown, 10 polynuclear aromatic compounds were observed at concentrations of up to 100 $\mu g/m^3$.

The studies cited above address the potential fire fighter exposure through measurements outside the body. In 1997, two published studies demonstrated that the exposures do occur, by measuring the chemical uptake in the bodies of individual fire fighters. Feuneckes *et al.* (1997) used personal air sampling to assess the exposure of fire fighting trainers in the Royal Netherlands Navy to polycyclic aromatic hydrocarbons (PAH), and then monitored the uptake of PAH by measuring the concentration of 1-hydroxypyrene, a metabolite of pyrene, in urine, which occurred despite the use of protective respirators and protective clothing. Their sample size was small, but the exposed fire fighters excreted concentrations of 1-hydroxypyrene at 25 – 30 percent of the levels that coke oven workers, who are known to be exposed to benzo(a)pyrene at very high level. Moen and Ovrebo (1997) performed similar studies in Norway, finding small, but significant increases in levels of urinary 1-hydroxypyrene after fire fighting.

Conclusion. Based on a review of the available data, ample documentation for potential and actual exposure of fire fighters to carcinogenic chemicals exists in the literature. Consequently, it is reasonable to conclude that fire fighters as a class suffer greater exposure to toxic and carcinogenic chemicals than the general population, although a quantification of that exposure and the resulting dose on an individual basis is currently not possible. Proper and maximum use of personal protective equipment, while certainly useful to help mitigate most exposures, is not fail-safe against some exposures, given the realities of the fire fighting profession.

Attachment 4. Fire fighters and cancer risk, summary of epidemiological studies.

Introduction. This review includes 23 epidemiological studies of cancer risk among fire fighters. For this structured review, specific criteria for assessing each study were established prior to evaluating any of the studies. As each study was reviewed, the following data were abstracted from the study for inclusion in summary tables: the number of study subjects (fire fighters); the number of referents (controls); the source of cases; the sources of referents; the job titles of study subjects; specific exposures measured; general groups of exposures measured; exposures measured from sources other than working as a fire fighter; disease outcome measures --cancer incident case, cancer death; source of incident or mortality data; cancer sites included in the study; number of cases of each cancer site; measure of risk (PMR, SMR, OR); measure of statistical significance; and dose response measure. The studies were then grouped by study design--Standard Mortality Ratio (SMR) cohort study (Tables 1 - 4), Proportional Mortality Ratio (PMR) cohort study (Tables 5 - 8), and case control study for review (Tables 9 – 12).

Review. Summary tables show the study design, participants, exposure measures, and results for 17 SMR cohort studies, four PMR studies, and two case control studies. None of the studies measured specific chemicals or agents that may have been carcinogens, nor did they measure other risk factors or non-fire fighting exposures. There were some attempts to measure the amount of active duty and exposure times along with the general job classification. Further, most studies attempted to measure dose response by examining the increased risk of specific cancers in terms of numbers of years on the job or years since first employment as a fire fighter. Death information was obtained primarily from official death certificates, rather than from retirement files or other sources.

Overall, these studies provide limited evidence of elevated cancer risk among fire fighters. They do, however, indicate useful areas for further research.

Most of these studies evaluated the risk of all cancers combined, with 13 SMR studies and three PMR studies finding neither elevated nor decreased risk. One study observed significantly lower risk than the comparison population, while four studies found significantly elevated risk, with one showing excess risk among fire fighters 65 and older, another among those with 40 plus years of employment, and another only for those with latency of 50 or more years.

The risk of lung cancer was not elevated or diminished in three PMR studies, one case control study, and 14 SMR studies. One case control study and three SMR studies found elevated risk. The case control study showed elevated risk of lung cancer among fire fighters for all lung cancers and for small cell and squamous cell lung cancers. The SMR studies found elevated risk among specific age groups (65+, 30 - 75 and 60 - 74) of fire fighters or within an exposure group of 35 years or more.

The risk of cancer of the brain was significantly elevated in five SMR studies. Ten SMR studies, one case control study and one PMR study found neither excess risk nor decreased risk for fire fighters. One of the studies showing elevated risk of brain cancer among fire fighters showed an overall elevated risk. Another showed risk among subsets of fire fighters when comparisons were made with the general population. In the same study, when comparisons were made with police, no elevated risk was observed. Two studies showed elevated risk among younger fire fighters -- those 18 - 39. Excess risk also was shown in these studies for various lengths of employment – 0 - 19 years, 30 plus years, less than 20 years, and 20 - 29 years. One study showed an elevated risk among individuals who had fought 1,000 fires or more or had a latency of 30 - 40 years.

There is limited evidence of increased risk of stomach cancer among fire fighters, with one study showing elevated risk overall and three studies showing elevated risk among fire fighters with 30 plus years of exposure or combating more than 1,000 fires. There also were eight studies that showed neither elevated nor decreased risk of stomach cancer. Similarly, for skin cancer, seven studies showed no differences in risk, while four studies showed some elevation of risk; two of these were PMR studies. One SMR study showed elevated risk when fire fighters were compared to the general population, but no elevation in risk when they were compared to police.

Prostate and colon cancer, two other major sites of concern, each had just two studies with elevated risk among specific subsets of fire fighters. In contrast, nine SMR studies found no difference in risk for prostate cancer, while seven SMR studies and one case control study found no difference in risk of colon cancer in comparison to the general population.

The majority of studies showed no elevated or decreased risk of bladder cancer among fire fighters (8 studies), while one study showed significantly lower risk than the comparison group and two studies observed elevated risk. Similarly, one study found elevated risk of liver cancer among fire fighters with 30 plus years of exposure, but the other six studies observed no difference in risk.

When compared to the general population, no difference in risk was seen in any study for cancers of the pancreas, esophagus, larynx, testis, eye, thyroid, oral cavity (one study found significantly reduced risk among fire fighters), and Hodgkins disease. For cancers of the kidney, esophagus, intestine, digestive tract, and rectum, the majority of studies found no difference in risk and in each case the studies that did see increased risk were either PMR studies or just one study showed such risk. For kidney cancers one study observed significant decreased risk.

Studies of leukemias, for the most part, observed no elevated or decreased risk among fire fighters (9 studies), while two PMR studies, one case control study comparing fire fighters to policemen, found elevated risk among fire fighters as did one SMR study among those exposed for 30 plus years. One study also observed significantly reduced risk of leukemia among fire fighters.

Similarly, studies of lymphomas found no elevated or decreased risk in 12 reports. Four studies observed elevated risk; one in a PMR study, one in a case control study that observed elevated risk among those 55 - 74 years old, and two among those with 30 plus years of exposure or at age 65 plus years.

Conclusion. An evaluation was conducted of 23 epidemiological studies of cancer risk among fire fighters. In terms of risk assessment, it is reasonable to conclude that for a few cancer sites, the evidence is suggestive of limited hazard identification. The studies evaluated cannot be used for quantitative risk assessment, since none of them measured actual exposures.

For brain cancer, fire fighters with longer years of exposure appear to have some elevated risk. Similarly, there is some evidence of increased risk of stomach cancer among fire fighters with 30 plus years of exposure. These results must be considered in the context of the small number of cases upon which these observations were made. The published studies are likely to provide useful leads for more specific research. For brain cancer, in addition to studying fire fighters with longer years of exposure, the observations made in two studies of elevated risk among younger fire fighters should be followed up with more specific investigations. Cancers occurring in these younger fire fighters could be due to exposures that occurred in childhood or prior to any employment as a fire fighter, or there may be more intense exposure early in employment as a fire fighter.

Further research also may be useful for lung cancer, skin cancer, and leukemias and lymphomas. Although the weight of evidence of each of these sites indicates no elevated risk, the few studies that did find excess risk warrant further investigation to attempt to resolve the conflicting evidence. In particular, since fire fighters are exposed to diesel exhaust, it would be important for future studies to investigate the risk of lung cancer among those exposed to diesel exhaust. Future studies also should utilize cancer incidence as the disease outcome measure, rather than mortality. This will ensure complete ascertainment of cancer cases and enhance the ability to evaluate risk by specific cell type for cancers such as lung and brain.

It is important to recognize that none of the studies evaluated measured actual exposures. All used length of employment as a fire fighter to measure exposure and a few extended this to defining exposure as active duty in fire combat, exposure to combustion products or smoke, or a weighted index of fires fought/station/year/fire fighter.

It is equally important to recognize that the majority of the evaluated studies found no elevated risk of cancer among fire fighters. In addition, for some cancer sites for which there was limited suggestion of increased risk, the evidence was often conflicting; e.g., with studies that showed both significantly elevated and significantly decreased risk or studies that showed risk in individuals with less exposure as well as among individuals with more exposure. Given the limits in study design and exposure measures; additional research will need to focus on the risk of selected cancers, for which limited evidence suggests the possibility of elevated risk, and employ improved measures of exposure.

Table 1. **Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) - Study Subjects*.**

Study No.*	Total N Subjects	Source of Cases	Total N Referents	Source of Referents
1	1559	Los Angeles City Fire Fighters	N/A**	U.S. male mortality rates
2	2289	Seattle Fire Department "Active Duty"	N/A	U.S. white males
3	886	Fire Fighters- Denmark	47694	Census- Denmark- Men age 15-69 employed in: Military services, Post and Telegraph Services, Police Force and Prison Administration, Nurses, Traffic System Operators, Pilots in Civil Aviation
4	3328	Active Fire Fighters in Alberta, Canada Edmonton and Calgary	N/A	Mortality Statistics- male residents of Alberta Alberta Vital Statistics
5	990	Western Australia Fire Brigade	N/A	Western Australian men
6	4546	Fire Fighters- Seattle, Tacoma, WA and Portland, OR	N/A	U.S. white male mortality rates and male police from the same cities
7	4540	Fire Fighters- Seattle, Portland, Bellvue, Tacoma, and Kent	3862	Male Police Officers- Seattle, Portland, Bellvue, Tacoma, and Kent and U.S. white males
8	5995	6 Fire Departments in Metropolitan Toronto	N/A	White Male Ontario population
9	5655	Boston Fire Department	N/A	Massachusetts Male Population U.S. Population Statistics
10	4546	Fire Fighters- Seattle, Portland, Tacoma, Bellvue, Kent	3676	Male Police Officers- Seattle, Portland, Bellvue, Tacoma, and Kent and U.S. white males
11	1867	Buffalo Fire Fighters	N/A	U.S. male mortality rates
12	1153	Fire Fighters- Stockholm	N/A	Stockholm population
13	3066	San Francisco Fire Department	N/A	U.S. population mortality rates
14	2865	Firemen- Victoria, Australia	N/A	Victorian population
15	1832	Ontario Fire Department	N/A	Ontario Male Death Rates
16	2447	Seattle and Tacoma Fire Fighters	1878	Seattle and Tacoma Policeman Reference incidence rates from King, Pierce, and Snohomish Counties (metropolitan area)

Key to studies referenced in this table: **1 = Lewis, Bierman and Faith, 1982; **2** = Heyer *et al*., 1990; **3** = Hansen, 1990; **4** = Guidotti, 1993; **5** = Eliopulos *et al*., 1984; **6** = Demers, Heyer and Rosenstock, 1992; **7** = Rosenstock *et al*., 1987; **8** = Aronson, Tomlinson and Smith, 1994 & L'Abbe and Tomlinson, 1992; **9** = Musk *et al*., 1978; **10** = Rosenstock and Demers, 1991; **11** = Vena and Fiedler, 1987; **12** = Tornling, Gustavsson and Hogstedt, 1994; **13** = Beaumont *et al*., 1991; **14** = Staples, Berry and Giles, 1993; **15** = Mastromatteo, 1959; **16** = Demers *et al*., 1994.
**N/A indicates information not available in text or not applicable to the study.

Table 2. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) - Exposure*.

Study No.*	Job Title	Specific Chemical or Agent	General Chemical or Agent	Other Exposures (Non-fire fighting)
1	Fire fighter	N/A**	N/A	No
2	Fire fighter	N/A	"Active Duty"	No
3	Fire fighter, Fireman	N/A	Combustion effluents	No
4	Fire fighter	N/A	Fire smoke and combustion products	No
5	Fire fighter	N/A	N/A	No
6	Fire fighters	N/A	N/A	No
7	Fire fighters	N/A	Active Duty in Fire Combat	No
8	Fire fighters	N/A	N/A	No
9	Fire fighters	N/A	N/A	No
10	Fire fighters	N/A	Active Duty in Fire Combat	No
11	Fire fighters	N/A	N/A	No
12	Fire fighters	N/A	Exposure Index calculated with approximate number of fires/ firefighter/station/year	No
13	Fire fighters	N/A	N/A	No
14	Firemen	N/A	N/A	No
15	Firemen	N/A	N/A	No
16	Fire fighters	N/A	Combustion products	No
17	Fire fighter	N/A	N/A	No

*Key to studies referenced in this table: **1** = Lewis, Bierman and Faith, 1982; **2** = Heyer *et al*., 1990; **3** = Hansen, 1990; **4** = Guidotti, 1993; **5** = Eliopulos *et al*., 1984; **6** = Demers, Heyer and Rosenstock, 1992; **7** = Rosenstock *et al*., 1987; **8** = Aronson, Tomlinson and Smith, 1994 & 1992; **9** = Musk *et al*., 1978; **10** = Rosenstock and Demers, 1991; **11** = Vena and Fiedler, 1987; **12** = Tornling, Gustavsson and Hogstedt, 1994; **13** = Beaumont *et al*., 1991; **14** = Staples, Berry and Giles, 1993; **15** = Mastromatteo, 1959; **16** = Demers *et al*., 1994; **17** = L'Abbe and Tomlinson.
**N/A indicates information not available in text or not applicable to the study.

Table 3. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Disease Outcome Measure*.

Study No*.	Incident Case	Source of Incident Data	Death	Source of Death Information
1			350	Death Certificates
2			383	Death Certificates
3			57	Death Certificate
4			370	Death Certificate
5			116	Death Certificate
6			1169	Death Certificate
7			889 Fire Fighters/ 508 Police	Death Certificate
8			777	Death Certificate
9			2470	Death Certificate
10			1173 Fire Fighters/ 714 Police	Death Certificate
11			470	Death Certificate
12	127	National Cancer Register	316	Death Certificate
13			1186	Death Certificate
14	50	Victorian Cancer Registry		
15			271	Death Certificate
16	242	Cancer Surveillance System of the Fred Hutchinson Cancer Research Center		
17			777	Ontario Cancer Treatment and Research Foundation

*Key to studies referenced in this table: **1** = Lewis, Bierman and Faith, 1982; **2** = Heyer *et al*., 1990; **3** = Hansen, 1990; **4** = Guidotti, 1993; **5** = Eliopulos *et al*., 1984; **6** = Demers, Heyer and Rosenstock, 1992; **7** = Rosenstock *et al*., 1987; **8** = Aronson, Tomlinson and Smith, 1994 & 1992; **9** = Musk *et al*., 1978; **10** = Rosenstock and Demers, 1991; **11** = Vena and Fiedler, 1987; **12** = Tornling, Gustavsson and Hogstedt, 1994; **13** = Beaumont *et al*., 1991; **14** = Staples, Berry and Giles, 1993; **15** = Mastromatteo, 1959; **16** = Demers *et al*., 1994; **17** = L'Abbe and Tomlinson.

Table 4. **Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites*.**

Study No.*	Site		N Cases	Risk Measure/Result	Statistical Significance (Confidence Interval)	Dose Response Measured
1		**Age at death**			Not stated	No
	Brain	<60 years	13	SMR / 229.3		
		>60 years	1	SMR / 20.9		
	Prostate	<60 years	6	SMR / 216.6		
		>60 years	41	SMR / 105.8		
	Lung	<60 years	45	SMR / 53.2		
		>60 years	42	SMR / 110.8		
	Colon	<60 years	8	SMR / 70.7		
		>60 years	37	SMR / 111.4		
	Bladder	<60 years	6	SMR / 78.5		
		>60 years	9	SMR / 101.8		
	Stomach	<60 years	6	SMR / 63.3		
		>60 years	10	SMR / 44.5		
	Liver	<60 years	3	SMR / 38.4		
		>60 years	2	SMR / 41.5		
	Rectal	<60 years	3	SMR / 29.5		
		>60 years	4	SMR / 58.9		
	Pancreas	<60 years	4	SMR / 55.0		
		>60 years	12	SMR / 69.4		
	Leukemia	<60 years	4	SMR / 63.9		
		>60 years	11	SMR / 91.8		
	All Cancers	<60 years	98	SMR / 68.3		
		>60 years	252	SMR / 81.3		

*Key to studies referenced in this table: **1** = Lewis, Bierman and Faith, 1982; **2** = Heyer *et al*., 1990; **3** = Hansen, 1990; **4** = Guidotti, 1993; **5** = Eliopulos *et al*., 1984; **6** = Demers, Heyer and Rosenstock, 1992; **7** = Rosenstock *et al*., 1987; **8** = Aronson, Tomlinson and Smith, 1994 & 1992; **9** = Musk *et al*., 1978; **10** = Rosenstock and Demers, 1991; **11** = Vena and Fiedler, 1987; **12** = Tornling, Gustavsson and Hogstedt, 1994; **13** = Beaumont *et al*., 1991; **14** = Staples, Berry and Giles, 1993; **15** = Mastromatteo, 1959; **16** = Demers *et al*., 1994; **17** = L'Abbe and Tomlinson.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result	Statistical Significance (Confidence Interval)	Dose Response Measured
2	All Cancer	92	SMR / 96	(77, 118)	Yes
	Digestive	29	SMR / 106	(71, 152)	
	Esophageal	1	SMR / 44	(1, 250)	
	Stomach	6	SMR / 113	(41, 247)	
	Intestine	7	SMR / 79	(32, 164)	
	Rectal	2	SMR / 65	(8, 237)	
	Respiratory	32	SMR / 101	(69, 143)	
	Lung	29	SMR / 97	(65, 139)	
	Brain/ Nervous	3	SMR / 95	(20, 279)	
	Lymphatic/ Hematopoietic	12	SMR / 126	(65, 222)	
	Leukemia	7	SMR / 173	(70, 358)	
	Other	3	SMR / 225	(47, 660)	
	Lung: 65+ years of age	18	SMR / 177	(105, 279)	
	30+ years of Experience:				
	- Other lymphatic	2	SMR / 989	(120, 3571)	
	- Leukemia	3	SMR / 503	(104, 1470)	
3			Age 30-49 50-59 60-74 30-74	Age 30-49 50-59 60-74 30-74	No
	All Cancer Sites	21	SMR/ 439 96 193 173	(142, 1024) (31, 225) (88, 366) (104, 270)	
	Lung	9	SMR/ 0 135 317 220	(0, 149) (16, 488) (117, 691) (95, 434)	
	Non-Pulmonary Cancer	12	SMR/ 575 81 108 150	(187, 1341) (17, 236) (22, 317) (75, 268)	
4	Malignant Neoplasms	92	126.6	(102.0, 155.2)	Yes
	Oral	2	113.6	(13.7, 410.4)	
	Stomach	6	80.9	(29.7, 176.0)	
	Colon and Rectum	14	161.4	(88.3, 270.9)	
	Pancreas	5	155.1	(50.4, 362.0)	
	Lung	24	142.0	(91.0, 211.4)	
	Skin	0	0.0	(0.0, 331.2)	
	Prostate	8	146.1	(63.1, 287.9)	
	Bladder	4	315.7	(86.0, 808.3)	
	Kidney and Ureter	7	414.0	(166.4, 853.1)	
	Brain	3	146.6	(30.3, 428.5)	
	Leuke., lymph., myeloma	10	126.4	(60.6, 232.5)	
	Lung 35+ exposure (yrs x weighted exposure index)	4	408.0	$p < 0.05$	

*Key to studies referenced in this table: refer to first page of Table 4.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result		Statistical Significance (Confidence Interval)		Dose Response Measured
5	All Neoplasms	30	SMR/ 1.37	SMR / 1.21	(0.93-1.36)	(0.74, 1.56)	Yes
	Respiratory	7	SMR/ 1.04	SMR / 0.84	(0.42, 2.13)	(0.33, 1.71)	
	Stomach	5	SMR/ 2.02		(0.65, 4.70)		
	Intestinal	4	SMR/ 1.59		(0.43, 4.07)		
	Other Digestive	3	SMR/ 0.88		(0.18, 2.58)		
	Genitourinary	4	SMR/ 1.08		(0.29, 2.76)		
	Lymphohaematopoietic	3	SMR/ 1.88		(0.39, 5.50)		
	Other Cancer	4	SMR/ 2.97		(0.81, 7.60)		
6			U.S. white men	Police	U.S. white men	Police	Yes
	All Cancer	291	SMR / 0.95	IDR**/ 0.97	(0.85, 1.07)	(0.80, 1.17)	
	Oral and Pharyngeal	7	SMR / 0.81		(0.33, 1.66)		
	Oseophageal	6	SMR / 0.83		(0.30, 1.80)		
	Stomach	16	SMR / 1.07		(0.61, 1.73)		
	Colon	24	SMR / 0.85	IDR / 1.58	(0.54, 1.26)	(0.73, 3.43)	
	Rectal	8	SMR / 0.95	IDR / 0.89	(0.41, 1.87)	(0.30, 2.66)	
	Biliary passages and Liver	6	SMR / 1.19	IDR / 0.71	(0.44, 2.59)	(0.19, 2.71)	
	Pancreatic	14	SMR / 0.89		(0.49, 1.49)		
	Laryngeal	2	SMR / 0.47		(0.06, 1.70)		
	Lung	95	SMR/ 0.96	IDR / 0.95	(0.77, 1.17)	(0.67, 1.33)	
	Prostate	30	SMR / 1.34	IDR / 1.43	(0.90, 1.91)	(0.71, 2.85)	
	Kidney	2	SMR / 0.27		(0.03, 0.97)		
	Bladder and other urinary	2	SMR / 0.23	IDR / 0.16	(0.03, 0.83)	(0.02, 1.24)	
	Skin	6	SMR / 0.98	IDR / 1.12	(0.36, 2.13)	(0.27, 4.76)	
	Brain/nervous sys. tumor	22	SMR / 2.09	IDR / 1.88	(1.31, 3.17)	(0.82, 4.31)	
	-10-19 yr. Employment	8	SMR / 3.53		(1.5, 7.0)		
	-30 yr. Since 1st Employ.	14	SMR / 2.63		(1.4, 4.4)		
	-18-39 years of age	5	SMR / 3.75		(1.2, 8.7)		
	Brain/nervous sys. cancer	18	SMR / 2.07	IDR / 1.63	(1.23, 3.28)	(0.70, 3.79)	
	Lymphatic / Hematopoietic	37	SMR/ 1.31	IDR / 1.03	(0.92, 1.81)	(0.62, 1.73)	
	Lymphosarcoma and reticulosarcoma	7	SMR / 1.42	IDR / 0.81	(0.57, 2.93)	(0.30, 2.22)	
	Hodgkin's disease	3	SMR / 1.05		(0.22, 3.08)		
	Leukemia	15	SMR / 1.27	IDR / 0.80	(0.71, 2.09)	(0.38, 1.70)	
	Other Lymph/heme	12	SMR / 1.40	IDR / 1.40	(0.72, 2.40)	(0.48, 4.07)	

*Key to studies referenced in this table: refer to first page of Table 4.

**IDR indicates Incidence Density Ratios or comparison in two populations of the incidence of a specified disease, expressed as the number of new cases per total number of person-years at risk.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result		Statistical Significance		Dose Response Measured
7			U.S. white males	Police	U.S. white males	Police	Yes
	All Cancers	195	SMR / 94	SMR / 87		p<0.05	
	Buccal Cavity and Pharynx	5	SMR / 76				
	Digestive organs	54	SMR / 89	SMR / 96			
	Esophagus	5	SMR / 103				
	Stomach	13	SMR / 109				
	Large Intestine	15	SMR / 77				
	Rectum	6	SMR / 88				
	Biliary passages and liver	4	SMR / 113				
	Liver not specified	0	SMR / 0				
	Pancreas	11	SMR / 97				
	Respiratory system	66	SMR / 97	SMR / 85			
	Larynx	2	SMR / 65				
	Trachea, Bronchus, Lung	62	SMR / 97	SMR / 86			
	Other Respiratory	2	SMR / 263				
	20-29 yr Exposure	40	SMR / 133		p<0.10		
	Male Genital Organs	14	SMR / 87				
	Prostate	14	SMR / 97				
	Other male genital	1	SMR / 65				
	Urinary Organs	2	SMR / 17		p<0.01		
	Kidney	2	SMR / 39				
	Bladder and other urinary	0	SMR / 0		p<0.01		
	Lymphatic and Heme	25	SMR / 124	SMR / 60		p<0.01	
	1960-1969 Time Period	14	SMR / 262		p<0.01		
	Lymphosarcoma and retic.	5	SMR / 84	SMR / 26		p<0.01	
	Hodgkin's disease	3	SMR / 115	(zero expected)			
	Leukemia and aleukemia	12	SMR / 138	SMR / 55		p<0.05	
	Other lymph and heme	5	SMR / 173	SMR / 161			
	Other and Unspecified	29	SMR / 115				
	Melanoma of skin	5	SMR / 122				
	Brain and other nervous	11	SMR / 170	SMR / 123			
	Age 15-39	4	SMR / 279		p<0.05		
	10-19 yr. Exposure	5	SMR / 342		p<0.05		
	Thyroid gland	1	SMR / 138				
	Connective tissue	3	SMR / 362				
	Unspecified- Brain	3	SMR / 217				

*Key to studies referenced in this table: refer to first page of Table 4.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result	Statistical Significance (Confidence Interval)	Dose Response Measured
8	All Malignant Neoplasms	199	SMR / 105	(91, 120)	Yes
	Pharnyx	4	SMR / 139	(38, 357)	
	Esophagus	2	SMR / 40	(5, 143)	
	Stomach	7	SMR / 51	(20, 105)	
	Colon	11	SMR / 60	(30, 108)	
	Rectum	13	SMR / 171	(91, 293)	
	Liver	2	SMR / 84	(10, 305)	
	Pancreas	14	SMR / 140	(77, 235)	
	Larynx	1	SMR / 37	(1, 206)	
	Trachea, Bronchus, Lung	54	SMR / 95	(71, 124)	
	Malignant Melanoma	2	SMR / 73	(9, 263)	
	Prostate	16	SMR / 132	(76, 215)	
	Testis	3	SMR / 252	(52, 737)	
	Bladder	7	SMR / 128	(51, 263)	
	Kidney	2	SMR / 43	(5, 156)	
	Brain and other nervous	14	SMR / 201	(110, 337)	
	Lymph and heme	18	SMR / 98	(58, 156)	
	Other Cancers	20	SMR / 238	(145, 367)	
9	All Cancer	367	SMR / 86	Not Stated	No
	Digestive	153	SMR / 80		
	Respiratory	70	SMR / 88		
	Genitourinary	64	SMR / 92		
	Brain	8	SMR / 103		
	Lymph and Heme	22	SMR / 63		
	Other Cancer	50	SMR / 114		

*Key to studies referenced in this table: refer to first page of Table 4.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.	Site	N Cases	Risk Measure/Result		Statistical Significance (Confidence Interval)		Dose Response Measured
10			U.S white males	Police	U.S white males	Police	Yes
	All Cancers	291	SMR / 0.95	IDR**/ 0.97	(0.85, 1.07)	(0.80, 1.17)	
	Buccal Cavity and Pharynx	7	SMR / 0.80		(0.32, 1.65)		
	Digestive	73	SMR / 0.86		(0.68, 1.08)		
	Esophagus	6	SMR / 0.82		(0.30, 1.79)		
	Stomach	16	SMR / 1.06		(0.61, 1.72)		
	Intestine	24	SMR / 0.84	IDR / 1.58	(0.54, 1.25)	(0.73, 3.43)	
	-<10 yr Exposure	4	SMR / 4.31		(1.3, 15)		
	Rectum	8	SMR / 0.95	IDR / 0.72	(0.41, 1.86)	(0.23, 2.30)	
	Pancreas	15	SMR / 0.95		(0.53, 1.56)		
	Biliary Passages and Liver	6	SMR / 1.18	IDR / 0.71	(0.43, 2.57)	(0.19, 2.71)	
	Respiratory	98	SMR / 0.93		(0.75, 1.13)		
	Larynx	2	SMR / 0.47		(0.06, 1.69)		
	Trachea, Bronchus, Lung	93	SMR / 0.93	IDR / 0.94	(0.75, 1.14)	(0.67, 1.33)	
	Prostate	30	SMR / 1.33	IDR / 1.43	(0.90, 1.90)	(0.71, 2.85)	
	-Age at death 65+ yrs.	26	SMR / 1.46		(1.0, 2.1)		
	Kidney	2	SMR / 0.27		(0.03, 0.97)		
	Bladder and other urinary	1	SMR / 0.11		(0.00, 0.62)		
	Other/Unspecified Cancers	40	SMR / 1.07		(0.76, 1.46)		
	Skin	6	SMR / 0.96	IDR / 1.12	(0.35, 2.10)	(0.27, 4.76)	
	Brain and Nervous sys	17	SMR / 1.93	IDR / 1.54	(1.13, 3.10)	(0.66, 3.62)	
	-10-19 yr Exposure	7	SMR / 3.62		(1.5, 7.5)		
	-30+ yr since 1st Employ.	11	SMR / 2.53	SMR / 3.04	(1.3, 4.5)	(1.0, 9.6)	
	-Age at death 18-39yrs.	4	SMR / 3.52		(1.0, 9.0)		
	Lymphatic and heme	37	SMR / 1.30	IDR / 1.03	(0.91, 1.79)	(0.62, 1.73)	
	-30+ yr Exposure	12	SMR / 2.05		(1.1, .6)		
	-30+ yr since 1st Employ	27	SMR / 1.48		(1.0, 2.2)		
	-Age at death 65+ yrs.	19	SMR / 1.61		(1.0, 2.5)		
	Lymphosarcoma & retic.	7	SMR / 1.41	IDR / 0.81	(0.57, 2.90)	(0.30, 2.22)	
	Hodgkin's disease	3	SMR / 1.04		(0.22, 3.04)		
	Leukemia and Aleukemia	15	SMR / 1.25	IDR / 0.80	(0.70, 2.07)	(0.38, 1.70)	
	Other lymph and heme	12	SMR / 1.38	IDR / 1.40	(0.72, 2.42)	(0.48, 4.07)	
	Unspecified nervous sys	2	SMR / 1.09		(0.13, 3.93)		

*Key to studies referenced in this table: refer to first page of Table 4.

**IDR indicates Incidence Density Ratios or comparison in two populations of the incidence of a specified disease, expressed as the number of new cases per total number of person-years at risk.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result	Statistical Significance (Confidence Interval)	Dose Response Measured
11	All malignant neoplasms	102	SMR / 109	(89, 132) 95%	Yes
	40+ years employment	32	SMR / 220	p<0.05	
	Years of latency- 50+	16	SMR / 211	p<0.01	
	Digestive organs/peritoneum	39	SMR / 138	(98, 189)	
	40+ years employment	16	SMR / 3.08	p<0.05	
	Esophagus	3	SMR / 134	(27, 391)	
	Stomach	7	SMR / 119	(48, 246)	
	Colon	16	SMR / 183	(105, 297)	
	40+ years employment	8	SMR / 471	p<0.05	
	Years of latency- 40-49	7	SMR / 265	p<0.01	
	Rectum	7	SMR / 208	(83, 428)	
	Liver	2	SMR / 98	(11, 352)	
	Pancreas	2	SMR / 38	(4, 136)	
	Respiratory system	28	SMR / 94	(62, 136)	
	Prostate	5	SMR / 71	(23, 165)	
	Bladder	9	SMR / 286	(130, 540)	
	40+ years employment	4	SMR / 571	p<0.05	
	Years of latency- 40-49	5	SMR / 453	p<0.01	
	Years of latency- 50+	3	SMR / 638	p<0.01	
	Kidney	3	SMR / 130	(26, 380)	
	Brain and other CNS	6	SMR / 236	(86-513)	
	20-29 years employment	3	SMR / 3.75	p<0.05	
	Years of latency- <20	3	SMR / 402	p<0.01	
	Years of latency- 20-29	3	SMR / 458	p<0.01	
	Lymphatic & hematopoietic	5	SMR / 55	(18, 129)	

*Key to studies referenced in this table: refer to first page of Table 4.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result	Statistical Significance (Confidence Interval)	Dose Response Measured
12	All Cancer	93	SMR / 102	(88, 125)	Yes
	Age: 65+ years	90	SMR / 109	(88, 134)	
	Stomach	12	SMR / 121	(62, 211)	
	Incidence: 1958-1986	18	SMR / 192	(114, 304)	
	Employment: >30 yrs.	12	SMR / 289	(149, 505)	
	Latency: <30 yrs.	5	SMR / 481	(155, 1122)	
	Latency: 30-40 yrs.	12	SMR / 616	(313, 1059)	
	Fires: >1000	12	SMR / 264	(136, 461)	
	Colon	6	SMR / 85	(31, 185)	
	Rectum/Anus	8	SMR / 207	(89, 408)	
	Liver	4	SMR / 149	(41, 381)	
	Pancreas	5	SMR / 84	(27, 196)	
	Lung	18	SMR / 90	(53, 142)	
	Prostate	14	SMR / 121	(66, 202)	
	Kidney	4	SMR / 110	(30, 281)	
	Brain	5	SMR / 279	(91, 651)	
	Latency: 30-40 yrs.	3	SMR / 507	(105, 1481)	
	Fires: >1000	4	SMR / 496	(135, 1270)	
	All haematopoietic cancer	3	SMR / 44	(9, 127)	

*Key to studies referenced in this table: refer to first page of Table 4.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result	Statistical Significance (Confidence Interval)	Dose Response Measured
13	All Cancer	236	RR***/ 0.95	(0.84, 1.08)	Yes
	Buccal Cavity and Pharynx	11	RR / 1.43	(0.71, 2.57)	
	Lip	2	RR / 6.17	(0.75, 22.29)	
	Tongue	2	RR / 1.06	(0.13, 3.86)	
	Pharynx	4	RR / 1.17	(0.32, 3.00)	
	Digestive and peritoneum	99	RR / 1.27	(1.04, 1.55)	
	Esophagus	12	RR / 2.04	(1.05, 3.57)	
	Stomach	22	RR / 1.31	(0.82, 1.99)	
	Intestine	24	RR / 0.99	(0.63, 1.47)	
	Rectum	13	RR / 1.45	(0.77, 2.49)	
	Biliary passages, liver, gb	9	RR / 1.91	(0.87, 3.63)	
	-30-39yr since 1st emplymt	2	RR / 3.87	p<0.05	
	-30+ yrs. emplymt	2	RR / 3.87	p<0.05	
	Pancreas	17	RR / 1.25	(0.73, 2.00)	
	Respiratory	63	RR / 0.83	(0.64, 1.06)	
	Larynx	3	RR / 0.80	(0.17, 2.35)	
	Trachea, Bronchus, Lung	60	RR / 0.84	(0.64, 1.08)	
	Genital	9	RR / 0.40	(0.18, 0.77)	
	Prostate	8	RR / 0.38	(0.16, 0.75)	
	Urinary	9	RR / 0.61	(0.28, 1.17)	
	Kidney	4	RR / 0.68	(0.19, 1.74)	
	Bladder and other urinary	5	RR / 0.57	(0.19, 1.35)	
	Other/Unspecified neoplasms	31	RR / 1.11	(0.76, 1.58)	
	Skin	7	RR / 0.69	(0.68, 3.49)	
	Brain and nervous system	5	RR / 0.81	(0.26, 1.90)	
	Lymphatic and hematopoietic	14	RR / 0.65	(0.35, 1.09)	
	Lymphosarcoma and retic.	4	RR / 0.89	(0.24, 2.29)	
	Leukemia and aleukemia	6	RR / 0.61	(0.22, 1.33)	

*Key to studies referenced in this table: refer to first page of Table 4.
***RR indicates Relative Risk.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) – Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result	Statistical Significance (Confidence Interval)	Dose Response Measured
14	All Cancer	50	SIR**** / 1.13	(0.84, 1.48)	Yes
	Age at Diagnosis: 65+	21	SIR / 2.14	(1.32, 2.37)	
	Upper aerodigestive tract	6	SIR / 1.46	(0.53, 3.18)	
	Colorectal	9	SIR / 1.36	(0.62, 2.59)	
	Age at Diagnosis: 65+	6	SIR / 3.65	(1.33, 7.94)	
	Pancreas	1	SIR / 1.03	(0.01, 5.75)	
	Lung	6	SIR / 0.77	(0.28, 1.68)	
	Melanoma	5	SIR / 1.08	(0.35, 2.53)	
	Prostate	5	SIR / 2.09	(0.67, 4.88)	
	Testis	2	SIR / 1.15	(0.13, 4.17)	
	Urinary tract	4	SIR / 1.02	(0.28, 2.62)	
	Non-Hodgkin's Lymphoma	4	SIR / 1.85	(0.50, 4.74)	
	Other haematopoietic	1	SIR / 0.94	(0.01, 5.25)	
	Leukemias	0	SIR / 0.00	(0.00, 3.55)	

*Key to studies referenced in this table: refer to first page of Table 4.
****SIR indicates Standard Incidence Ratio.

Table 4. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Standard Mortality Ratio (SMR) - Results by Cancer Sites* (continued).

Study No.*	Site	N Cases	Risk Measure/Result	Statistical Significance (Confidence Interval)	Dose Response Measured
15			Obsv/Exp for the years: 1921-53		No
	Cancers and other malignant tumors	34	34/30		
16	All Cancer	224	SIR**** / 1.1	(0.9, 1.2)	Yes
	Oral and Pharynx	11	SIR / 1.1	(0.6, 2.0)	
	Esophagus	4	SIR / 1.3	(0.4, 3.3)	
	Stomach	8	SIR / 1.4	(0.6, 2.7)	
	Colon	23	SIR / 1.1	(0.7, 1.6)	
	Rectum	12	SIR / 1.0	(0.5, 1.8)	
	Pancreas	6	SIR / 1.1	(0.4, 2.3)	
	Sinus	1	SIR / 2.2	(0.1, 12.4)	
	Larynx	5	SIR / 1.0	(0.3, 2.3)	
	Lung, Trachea, Bronchus	45	SIR / 1.0	(0.7, 1.3)	
	Melanoma of skin	9	SIR / 1.2	(0.6, 2.3)	
	Breast	1	SIR / 2.4	(0.1, 13.3)	
	Prostate	66	SIR / 1.4	(1.1, 1.7)	
	20-29 yr. Exposure	47	SIR / 1.5	(1.1, 2.0)	
	Bladder	18	SIR / 1.2	(0.7, 1.9)	
	Kidney	3	SIR / 0.5	(0.1, 1.6)	
	Ocular Melanoma	2	SIR / 5.2	(0.6, 18.8)	
	Brain	4	SIR / 1.1	(0.3, 2.9)	
	Thyroid	1	SIR / 0.8	(0.2, 4.2)	
	Hodgkin's Disease	1	SIR / 0.7	(0.0, 4.1)	
	Non-Hodgkin's Lymphoma	7	SIR / 0.9	(0.4, 1.9)	
	Multiple Myeloma	2	SIR / 0.7	(0.1, 2.6)	
	Leukemia	6	SIR /1.0	(0.4, 2.1)	

*Key to studies referenced in this table: refer to first page of Table 4.

****SIR indicates Standard Incidence Ratio.

Table 5. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/Proportional Mortality Ratio (PMR) - Study Subjects*.

Study No.*	Total N Subjects	Source of Cases	Total N Referents	Source of Referents
20	271	Fire fighters in New Jersey	615 Police	1) U.S. general population 2) New Jersey general population 3) New Jersey police
21	3084	Chicago Fire fighters	N/A*	U.S. Caucasian Males
22	5744	National Occupational Mortality Surveillance Fire fighters from 27 states	N/A	Not Stated
23	Not stated	Oklahoma City Fire Department	N/A	Mortality Statistics and Vital Statistics of the United States- white males for State of Oklahoma

*Key to studies referenced in this table: **20** = Feuer and Rosenman, 1986; **21** = Orris, Kahn and Melius, 1992; **22** = Burnett *et al*., 1994; **23** = Abrams [1974].
*N/A- Indicates information not available in text or not applicable to study.

Table 6. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/Proportional Mortality Ratio (PMR) - Exposure*.

Study No.*	Total N Subjects	Specific Chemical Or Agent	General Chemical Or Agent	Other Risk Factors
20	Fire Fighter/ Police	N/A*	N/A	No
21	Fire Fighter	N/A	N/A	No
22	Fire Fighter	N/A	N/A	No
23	Fire Fighters	N/A	Fire fighters on active, service-retired, resigned, dismissed or leave of absence statuses	No

*Key to studies referenced in this table: **20** = Feuer and Rosenman, 1986; **21** = Orris, Kahn and Melius, 1992; **22** = Burnett *et al*., 1994; **23** = Abrams [1974].
*N/A- Indicates information not available in text or not applicable to study.

Table 7. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/Proportional Mortality Ratio (PMR) – Disease Outcome Measure*.

Study No.*	Incident Data	Source of Incident Data	Death	Source of Death Information
20			271	Death Certificate
21			3084	Pension Fund Records
22			5744	Death Certificates
23			259	State Dept. of Labor, State Health Dept., State Insurance Commission, State Industrial Court, State Fire Marshal, Oklahoma Fire Fighters Association, City Personnel Office, City Clerk's Office, City Auditor's Office, Personnel records

*Key to studies referenced in this table: **20** = Feuer and Rosenman, 1986; **21** = Orris, Kahn and Melius, 1992; **22** = Burnett *et al*., 1994; **23** = Abrams [1974].

Table 8. Summary of results of epidemiological studies of cancer risk among fire fighters*: Cohort/ Proportional Mortality Ratio (PMR) – Results by Cancer Sites*.

Study No.*	Site	N Cases		Risk Measure/Result			Statistical Significance (Confidence Interval)			Dose Response Measured
20				US	Police	NJ	US	Police	NJ	Yes
	All Cancer	67		PMR / 1.15	1.07	1.00				
	Digestive	20		PMR / 1.45	0.91	1.11				
	Respiratory	23		PMR / 0.98	1.02	0.92				
	Skin	4		PMR / 2.70	1.35	1.90	P < 0.05			
	Leukemia	4		PMR / 1.86	2.76	1.77		P < 0.05		
21	All Cancer			PMR / 107			(99, 158)			No
	Intestine			PMR / 131			(104, 165)			
	Rectum			PMR / 164			(114, 230)			
22		Under age 65	Total	Under age 65		Total	Under age 65		Total	No
	Malignant Neoplasms	663	1636	PMR / 112		110	(104, 121)		(106, 114)	
	Rectum	18	37	PMR / 186		148	(110, 294)		(105, 205)	
	Lung	236	562	PMR / 98		102	(86, 112)		(94, 111)	
	Skin	24	38	PMR / 167		163	(107, 248)		(115, 221)	
	Bladder	9	37	PMR / 101		99	(46, 193)		(70, 137)	
	Kidney	24	53	PMR / 141		144	(90, 210)		(108, 189)	
	Brain and Nervous Sys.	19	38	PMR / 85		103	(52, 134)		(73, 141)	
	Lymph and Heme	85	169	PMR / 161		130	(129, 199)		(111, 151)	
	N-H Lymphoma	35	66	PMR / 161		132	(112, 224)		(102, 167)	
	Multiple Myeloma	11	34	PMR / 136		148	(68, 243)		(102, 207)	
	Leukemia	33	61	PMR / 171		119	(118, 240)		(91, 153)	
23	All Cancer	Not stated		PMR / 13.5%			Not Stated			Yes
	Respiratory Cancer			PMR / 4.30%						

*Key to studies referenced in this table: **20** = Feuer and Rosenman, 1986; **21** = Orris, Kahn and Melius, 1992; **22** = Burnett *et al*., 1994; **23** = Abrams [1974].

Table 9. Summary of results of epidemiological studies of cancer risk among fire fighters*: Case Control Studies - Study Subjects*.

Case Control Studies- Study Subjects				
Study No.	**Total N Cases**	**Source of Cases**	**Total N Referents**	**Source of Referents**
18	4431	Missouri Cancer Registry	11326	Missouri Cancer Registry
19	29990	Massachusetts Cancer Registry	Two groups -29277 Other statewide males -392 Police Officers	Massachusetts Cancer Registry

*Key to studies referenced in this table: **18** = Zahm *et al*., 1989; **19** = Sama *et al*., 1990.

Table 10. Summary of results of epidemiological studies of cancer risk among fire fighters*: Case Control Studies - Exposure*.

Study No.	Job Title	Specific Chemical or Agent	General Chemical or Agent	Other Risk Factors
18	Police, Firemen, Protective services	N/A**	N/A	Tobacco Use
19	Fire fighter	N/A	N/A	Cigarette Use

*Key to studies referenced in this table: **18** = Zahm *et al*., 1989; **19** = Sama *et al*., 1990.
**N/A- Indicates information not available in text or not applicable to study.

Table 11. Summary of results of epidemiological studies of cancer risk among fire fighters*: Case Control Studies – Disease Outcome Measure*.

Study No.*	Incident Data	Source of Incident Data	Death	Source of Death Information
18			N/A**	N/A
19			N/A	N/A

*Key to studies referenced in this table: **18** = Zahm *et al*., 1989; **19** = Sama *et al*., 1990.
**N/A- Indicates information not available in text or not applicable to study.

Table 12. Summary of results of epidemiological studies of cancer risk among fire fighters*: Case Control Studies – Results by Cancer Sites*.

Study No.*	Site	N Cases	Risk Measure/Result		Statistical Significance (Confidence Interval)		Dose Response Measured
18	Lung	60	OR** / 1.6		(1.1, 2.3) 95%		No
	Small Cell	25	OR / 1.3		(1.3, 4.2)		
	Squamous Cell	24	OR / 1.8		(1.1, 3.0)		
19			Police	State	Police	State	No
	Melanoma	18	OR / 138	OR / 292	(60, 319)	(170, 503)	
	Age 55-74 at Death	11	OR / 513		(150, 1750)		
	Bladder	26	OR / 211	OR / 159	(107, 414)	(102, 250)	
	Lymphoma	14	OR / 327	OR / 159	(119, 898)	(89, 284)	
	Age 55-74 at Death	10	OR / 538		(150, 1924)		
	Pancreas	6	OR / 319	OR / 98	(72, 1415)	(42, 226)	
	Leukemia	6	OR / 267	OR / 112	(267, 1154)	(48, 259)	
	Colon	33	OR / 104	OR / 120	(59, 182)	(80, 182)	
	Rectum	22	OR / 97	OR / 135	(50, 188)	(84, 219)	
	Lung	71	OR / 130	OR / 122	(84, 203)	(87, 169)	
	Brain	5	OR / 152	OR / 86	(39, 592)	(34, 215)	
	Non-Hodgkins Lymphoma	14	OR / 327	OR / 159	(119, 898)	(89, 284)	
	Leukemia	6	OR / 267	OR / 1.2	(62, 1154)	(48, 259)	

*Key to studies referenced in this table: **18** = Zahm *et al*., 1989; **19** = Sama *et al*., 1990.
**OR indicated Odds Ratio.